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This project provided instrumentation for dynamic data acquisition and experimental control for dynamic testing of materials and structural systems in the Structural Research Laboratory of the Department of Civil Engineering. The project resulted in the purchase of equipment to attain an intermediate speed data acquisition, to increase the number of channels of the very high speed data acquisition capability and to assure that these dynamic data acquisition systems are compatible with existing low speed data acquisition systems and the computers used for interpretation and analysis of the data. The project resulted in the purchase of equipment for the development of a simple computer based interactive control system for the loading devices. This capability will result in more efficient utilization of the laboratory facilities, and it will result in the application of more realistic loads and deformations to the structure. The project included only funding for the purchase of the equipment, but a substantial portion of the software development for interactive testing has been completed with work paid for by another research project. In addition, enhanced computing facilities have been developed to assist in this effort through additional funding provided by the University of Washington and the Hewlett Packard Corporation. The combined effects of these contributions greatly enhances the experimental capabilities of the laboratory.

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(Durip) Instrumentation for Data Acquisition and Control of Structural Experiments

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Final Technical Report

Abstract

This project provided instrumentation for dynamic data acquisition and experimental control for dynamic testing of materials and structural systems in the Structural Research Laboratory of the Department of Civil Engineering. The project resulted in the purchase of equipment to attain an intermediate speed data acquisition, to increase the number of channels of the very high speed data acquisition capability and to assure that these dynamic data acquisition systems are compatible with existing low speed data acquisition systems and the computers used for interpretation and analysis of the data. The project resulted in the purchase of equipment for the development of a simple computer based interactive control system for the loading devices. This capability will result in more efficient utilization of the laboratory facilities, and it will result in the application of more realistic loads and deformations to the structure. The project included only funding for the purchase of the equipment, but a substantial portion of the software development for interactive testing has been completed with work paid for by another research project. In addition, enhanced computing facilities have been developed to assist in this effort through additional funding provided by the University of Washington and the Hewlett Packard Corporation. The combined effects of these contributions greatly enhances the experimental capabilities of the laboratory.

Final Technical Report

General

This project provided instrumentation for dynamic data acquisition and experimental control for dynamic testing of materials and structural systems for the Structural Research Laboratory of the Department of Civil Engineering at the University of Washington. The equipment will be used in research performed by the faculty of the Structures, Geotechnical and Engineering Mechanics Program. The equipment was purchased from the Hewlett Packard Corporation (HP), the Vishay-Measurements Group Inc. and the MTS Corporation (MTS). These suppliers were selected because they have an extensive range of equipment for dynamic testing, and the laboratory already uses many items of equipment supplied by them.

Summary of the Existing Facilities Prior to this Research

The Structural Research Laboratory has more than 9,000 sq. ft. of usable floor space and a clear height of 15 to 40 feet. The laboratory space is serviced by several overhead crane systems. Approximately 8% of this space is a strong floor system with tie-down anchorage. There is a 2.3 million pound Baldwin Hydraulic Testing machine which is frequently used for qualification testing of large structural components. There are also 3 other smaller Baldwin machines which are frequently used for testing small structural components and material testing. MTS actuators are used for dynamic testing of structural systems and testing which requires cyclic loading. The laboratory has 60 GPM of hydraulic pumping capacity and more than 12 double acting actuators with load capacities between 5 kips and 220 kips for the MTS system. Hard pipelines have been installed for transmitting the hydraulic fluid to various parts of the laboratory, and local controls are provided at several locations. Numerous electronic controllers, wave form generators, and servo-valves are available. Most of the actuators are moveable and can be used in a wide range of experiments, but a few are dedicated to specific applications. One 110 kip actuator is part of a fixed frame testing machine, which is frequently used for material tests and crack propagation studies. Another 55 kip actuator is part of a very high speed load frame system (MTS 322.31). A 22 kip ram is used to power a small one dimensional shaking table for the simulation of earthquakes. A fourth 55 kips actuator is part of a small fixed frame MTS testing machine, and it is commonly used for testing of pavement materials. The remaining actuators are moveable and

can be used in a wide range of applications. They have been recently used in fatigue tests of bridge decks, structural bearings, and anchorages; tests into the inelastic behavior of structural components under seismic loading; tests evaluating the temperature dependent behavior of different structural components; and numerous other applications.

The laboratory had 4 HP Series 9000 computer systems for interpreting and analyzing data. The systems have between 1.25 and 4 MByte of usable memory and up to 126 MByte of hard disk storage. They have printers, plotters, and tape drives, and they can be interfaced with other mainframe computers through the Engineering College Computer Network. These machines have a 32 bit internal architecture, and they are capable of performing large calculations quite rapidly. Three of these four computers can be directly connected to two separate HP data acquisition systems (HP3497). These two data acquisition systems are relatively slow but they are very accurate. They are presently capable of handling more than 150 channels of strain gages, load cells, thermocouples, LVDT's, and other measurement devices, and they can readily be expanded to more than 1000 channels. However, these devices presently are capable of taking data at the rate of 40 readings per second and they can be extended only up to the rate of approximately 1000 readings per second. This rate was adequate for quasi static or very slow dynamic experiments, but it was inadequate for most practical dynamic applications. For very high speed experiments a digital oscilloscope was used. This provides extremely fast data acquisition for rapid strain rate experiments. However, it had a very limited number of channels of data acquisition capacity, and it records too much data for use in dynamic experiments which utilize longer periods and duration of vibration. Further, these instruments are not compatible with the HP computer systems, and as a result the data could not be analyzed with the same methods used for the slower tests. This resulted in considerable inefficiency, since considerable time was lost in learning the different systems.

Major Objectives of the Instrumentation Request

The equipment included in the proposal was to supplement these existing facilities. The instruments will be used in the Structural Research Laboratory of the Department of Civil Engineering at the University of Washington, and it will be used in research performed by the faculty of the Structures, Geotechnical and Engineering Mechanics Program. There are 11 faculty in this program, and they are very active in a wide range of research projects. However, Professors C. B. Brown, N. M.

Hawkins, A. H. Mattock, C. W. Roeder, and J. F. Stanton will be the primary users of the experimental equipment.

Prior to this research grant, the laboratory had a range of data acquisition systems for static and relatively slow dynamic testing. This data acquisition equipment was controlled by one of four different HP computers, which offered a substantial analysis capability, and the computers also had a number of printers, plotters, and methods of data transfer. The laboratory also had a very modest data acquisition capability for very rapid strain rate experiments (i.e.., experiments performed with strain rates in the order of 10^{-5} or 10^{-6} seconds), but this equipment was not compatible with the other computers. As a result, much of the data analysis and transfer capability was not available for this very high speed system. The laboratory had virtually no data acquisition capability in the intermediate range of dynamic response. The first major objective of this research program was to fill in this lack of intermediate speed data acquisition, to enhance the very high speed data acquisition, and to insure compatibility of all levels of the data.

The laboratory had a range of loading actuators, controllers, and power supply for dynamic testing of materials and structural systems. These systems can provide loads in a wide range of strain rates and loading configurations. The loads can simulate normal structural vibration, seismic excitation, fatigue loading and very rapid strain rates, such as blast loading. The load patterns were somewhat limited, however. The load pattern had to be defined before the experiment was started, and could be modified only by manual intervention. When structures are designed for seismic excitation, the load experienced by the structure is dependent upon the state of stress with the structure, and new test methods such as the pseudo dynamic computer on line simulation method allow the researcher to change the structural loading in response to its measured behavior. Further, recent studies in fatigue with variable amplitude loading show that the fatigue life is highly dependent upon the load history, and so it is again desirable to have an intelligent computer based control of the load history. The second major objective of this equipment proposal was the development of a simple computer based control system, which utilizes the measured response behavior, for the MTS load equipment.

Method of Purchase

The original proposal was for funding in the amount of $107,362 plus $24,780 as matching funds from the University of Washington.

Limitations in the available funds reduced this amount to $80,160 plus the University of Washington contribution. This funding reduction required a slight reduction in the scale of the planned effort, but it did not change the overall objectives.

The proposal was funded and the equipment was purchased in five major blocks from 3 suppliers. The purchase was divided in this manner, because it allowed a logical development of the equipment. That is, it allowed researchers to check the operation of the major items before many of the related components were purchased. This assured that the proper devices were purchased, that everything worked together, that the budget was not exceeded and that the researchers had time to check the various devices in a logical manner. The first two blocks included purchases from the Hewlett Packard and the MTS Corporations of moderately high speed devices and load controllers. This equipment has all been received, paid for and has already been used in at least one experiment. The third purchase group was a instructional class on using this equipment. The project provided funding for the tuition of this class and the University of Washington provided funding for the travel expenses. An advanced graduate student, Ph.D. Candidate - Stephen P. Schneider, attended this class. His salary was paid on another research grant and he has used this equipment to develop the software for controlling the equipment and developing advanced testing capabilities as noted later in this report.

The fourth major group was a purchase of very high speed data acquisition capabilities and additional modules and components for the earlier purchase. This purchase was delayed to assure that everything was compatible, and slight changes were made from the earliest plan to make the most efficient use of these funds in this purchase. These changes are those noted in Amendments A and B, and they permitted more efficient usage of the funding. Since this equipment was purchased later, it has been received, paid for and tested, but most of it has not yet been used in an actual research project. The final purchase group was a purchase of amplifiers with signal conditioning from Measurements Group (through Brett Associates as supplier). This final purchase was delayed because this equipment was of lowest priority. It was ordered several months ago and the payment is encumbered, but it has not yet been received or paid for. We expect delivery very shortly. It should be noted that the funding was inadequate to complete the planned purchase of this final group as outlined in the proposal and the amendments, and so the University of Washington provided additional funding to achieve the objective.

Equipment Purchased on this Grant

The following is a list of the equipment purchased on this grant. Please note that several model numbers may appear to be slightly different from those noted in the original proposal and the proposal amendments. This occurs because the addition or deletion of related pieces such as electronic cables, hydraulic hoses, or plug in pieces changed the model number, or these pieces had to be purchased separately while they were included in the general headings in the proposal. The items are -

Purchased from MTS -

3 MTS 406.11 Servocontrollers including built-in AC displacement conditioner and rack mounting kit

1 MTS 436.11 Control unit with counter, rack mount kit and power switch

1 Cable for MTS 436 to hydraulic power supply

3 Cables for MTS 406 to force transducer (30 ft)

3 Cables for MTS 406 to servovalves (dual) (30 ft)

1 Plug in nodule for MTS 406 for DC force transducer conditioner

Purchase from Hewlett Packard

3 HP5183A 2-channel waveform Recorders

1 HP3852A Data acquisition anc control mainframe

1 HP44703B Mainframe Extended Memory

1 13 Bit High Speed Voltmeter with 18 K buffer

1 HP3853A Extender Chassis

1 HP44701A 5-1/2 Digit Integrating voltmeter

3 HP44709A 20 channel FET multiplexer

5 HP44719A 120 ohm stain gage FET MUX

2 HP44727A 4 channel voltage DAC

2 HP 44720A 350 ohm strain gage FET MUX

1 HP 44458A data acquisition manager

3 HP 40651J Accelerometer kit with power supply

1 HP44429A Dual option voltage DAC assembly

2 HP44732A 4 channel 120 ohm dynamic strain gage multiplexer

1 HP44711A 24-channel high speed FET multiplexer

1 HP44727B 4-channel current DAC

Purchased from Micromeasurements through Brett & Associates

4 Model 2120A 2-channel signal conditioning amplifier units

1 Model 2110A Power supply

1 Model 2160 Portable Enclosure

Additional Accomplishments

A number of additional related accomplishments have resulted from this and related projects. First, the University of Washington received an additional grant from the National Science Foundation in March 1989 for research related to the seismic behavior of steel buildings. This research project will utilize much of the equipment purchased on this AFOSR grant, and as a result, the NSF funding has been used for graduate student support for a graduate student while he developed computer software for interactive control of seismic experiments. This software will permit computer on line actuator control of the research experiments. This test method will adjust the specimen loading to consider the true measured state of stress and strain in the specimen in addition to the dynamic loading. It will also be useful for subassemblage tests where the dynamic

behavior of the untested components of the total structure is also analytically considered in the test.

In addition, the University of Washington and a grant from the Hewlett Packard Corporation have permitted the purchase of two HP Series 300 Workstations for the laboratory. This workstations compliment existing computer facilities, but they provide greatly enhanced computing power and data storage, transmission and analysis capabilities. While, this AFOSR grant did not provide funding for either of these related accomplishments, the grant provided related equipment which made the related accomplishments possible.

Benefits of Project

This project will directly benefit several research projects which are planned and several which are already in progress. This includes a proposed continuation of at least one AFOSR project as well as funded projects through the National Science Foundation and the National Research Council. The project will have long term benefit in that the equipment should be in service for a number of years into the future.